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THE EFFECTS OF MAGNETIC STORM PHASES ON F-LAYER IRREGULARITIES FROM
AURORAL TO EQUATORIAL LATITUDES

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INTRODUCTION

With scintillation data collected at both high and equatorial latitudes for a series of magnetic storms, we are searching for means of identifying the parameters at high latitudes which produce effects at equatorial latitudes. We seek to understand the physics of development of irregularities both at high and at equatorial latitudes. The measurement of parameters which are necessary and sufficient to develop the irregularities can be used to forecast and predict when these irregularities interfere with communications and navigation operations. By using simultaneous measurements of the same parameters, rate of change of phase and total electron content, from a series of stations at high and equatorial latitudes, it is expected that a link may be forged between high latitude activity and equatorial irregularities.

SCIENTIFIC OBJECTIVES

The instability processes by which F layer irregularities develop are different for high latitude and for equatorial irregularities. At high latitudes it appears as if the turbulence produced during magnetic storm activity is the prime reason for high intensity irregularities. At equatorial latitudes instability mechanisms, primarily the Rayleigh Taylor instability, has been thought to be the primary reason for the growth of plume like irregularities near the magnetic equator. Using radio and optical observations, we would like to find the triggering mechanism for equatorial irregularity development. These could range from lower atmosphere conditions to substorm activity at high latitudes. The processes involve neutral winds in the ionosphere, horizontal and vertical gradients of electron density, velocity of F layer plasma, and shears in electron density.

APPROACH

For this study we have examined data which we are reducing from both magnetically quiet and magnetically disturbed periods. The studies use analysis of rate of change of phase fluctuations and total electron content. For both high and equatorial latitudes, we are using data from the International GPS Service for Geodynamics (IGS). Our concept is to study the rate of change of phase and the total electron content of the ionosphere and protonosphere from the GPS records. Thirty second values of phase differences between the 1.2 GHz and the 1.6 GHz signals of each GPS satellite were used. The data set consists of 30 second samples, thus we are recording irregularities larger than 6 km with our data reduction. This area of phase scintillation we have chosen to call our data phase fluctuations.

TASKS COMPLETED

A. AURORAL IRREGULARITY DEVELOPMENT

Recently we concentrated on two magnetic storms. One was the January 10, 1997 storm which is the subject of a large number of studies. The second of our studies uses data from the period in October 1996 when a large scale field program was underway in the equatorial region. Other observational teams had field programs in the Primer series of studies. We analyzed the equatorial data and then compared it with high latitude development. The high latitude comparisons and gathering of related data (magnetic and satellite measurements) has just commenced. Starting with characteristics of the irregularity development in magnetically quiet days, it was noted that the start and stop times of phase fluctuations correlated with the entry and exit into the irregularity oval. Maximum occurrence took place near magnetic midnight. The irregularity oval while matching the auroral oval in much of its behavior receded to very high latitudes during extended periods of magnetic quiet. During magnetic storms the irregularity oval expands equatorwards and polewards and phase fluctuations increase in intensity. While the geographic position of the station relevant to the oval is important during storms, the dynamics of each storm modifies the simple behavior shown during quiet times.

Good data were available for the month of October from several stations in the auroral region which made GPS observations similar to those available from equatorial latitudes. At auroral latitudes magnetic activity increases both intensity and occurrence of irregularities. The October data from Reykjavik, Iceland and from Flin Flan, Canada both near Corrected Magnetic Latitudes of 65° show activity directly correlated with magnetic activity throughout the month with the most intense fluctuations noted in the October 22-23 time period. Several other days showed high activity similar to that at equatorial latitudes. Although the auroral regions showed activity throughout the month, the two sub-auroral stations of Algonquin (57° CGL) and St. John's (54°) showed activity on far fewer days. Algonquin has phase fluctuations greater than 0.5 TECU/min on October 10, 13, 19-20, and 22-23 but St. John's showed similar excursions only on October 22-23. Effects did not penetrate very deeply into sub-auroral regions. A study of the storm of October 22-23 was initiated.

The processes of transfer of energy to lower latitudes within the ionosphere are complex. A shielding takes place at high latitudes which prevents penetration to middle latitudes. The timing and placement of the shielding is something we shall study.

Using GPS transmissions has advantages over ionosondes and HF backscatter in that the high GPS frequencies make the study immune to auroral and polar cap absorption. HF backscatter also suffers from Auroral E blanketing. However ionosondes are able to determine E and F layer critical frequencies and the state of auroral E and spread F. The high GPS frequencies do not show saturation in our studies while earlier high latitude studies of amplitude scintillations at 136 MHz or 250 MHz have shown saturation effects. Our conclusion at this time with the comparison of our GPS data with sounders is that high latitude turbulence is the source of auroral oval irregularities.

IMPACT FOR SCIENCE

The observations have now supplied via scintillation observations, phase fluctuation analysis and depletion studies, a fundamental data base that can be used to test and constrain models.

Although a comprehensive theory exists for the development of plumes, it is believed that a data base validating those hypotheses does not exist. It is necessary to quantitatively show observational parameters necessary and sufficient to produce plumes and levels of these parameters which fail to satisfy these conditions.

TRANSITION ACCOMPLISHED AND EXPECTED

We now can determine the expansion of the irregularity oval region during a magnetic storm when scintillation becomes a serious problem. The timing that we have seen by our analysis of phase scintillation during magnetic storms is a function of how close the station is to the irregularity oval, local time, and the particular characteristics of the magnetic storm.

The next step is to try to link magnetic activity and equatorial development of irregularities.

RESULTS/CONCLUSIONS

We now have an excellent data base at both equatorial and high latitudes.

We know that phase fluctuations exist across a distinct longitudinal region as would be expected from knowing the characteristics of plumes. Activity could be restricted to a narrow longitudinal region of several hundred kilometers or activity could be noted all across South America for example, a very large sector of longitudes. Can we match this with high latitude activity as shown either with magnetograms or with phase scintillation data at particular longitudes?

There are specific days that show activity of thin layers of irregularities or of plumes moderate in altitude (400-600 km) over 38° of longitude; there are days which show localized effects with much narrower longitude regions. Is there any aspect of high latitude phenomena which will help us forecast these days?

Some magnetic storms fail to produce very high altitude plumes. Can we forecast which storms will produce effects by their temporal development?

PUBLICATION

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